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No. 12.—Notes on the Iron Ore Deposits of Bilbao, Northern Spain.

BY

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[Presented at the Annual Meeting of the Canadian Mining Institute, on 6th March, 1901.]

MONTREAL, 1902.

Canadian Mining Institute

INCORPORATED BY AN ACT OF THE PARLIAMENT OF CANADA

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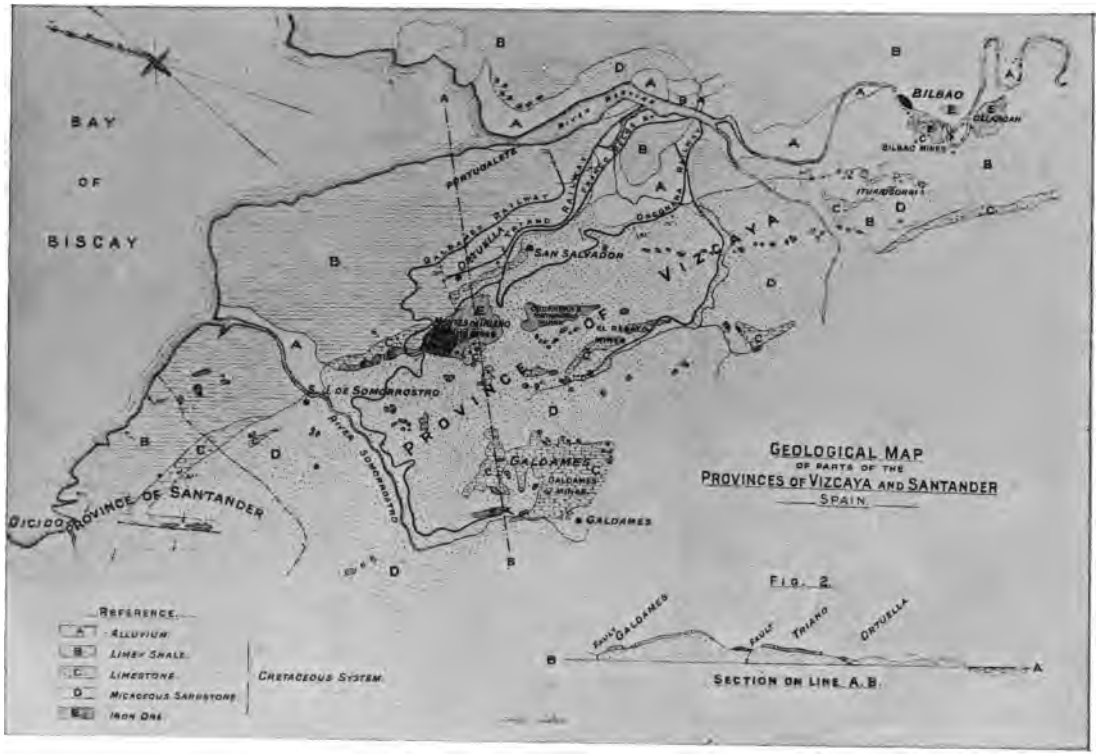
PUBLISHED BY AUTHORITY OF COUNCIL
AT THE OFFICE OF THE SECRETARY, OTTAWA
1901



GEOLOGICAL MAP
OF PARTS OF THE
PROVINCES OF VIZCAYA AND SANTANDER
SPAIN.

Fig. 2.

5640A
4-B

PLATE I.

ESPERANZA MINE.

Shows general character of the surface of the district and open cut from which Campanil is obtained.

Notes on the Iron Ore Deposits of Bilbao, Northern Spain.

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The Iberian peninsula, while producing comparatively little iron, is known to contain many large deposits of iron ore some of which have been worked from very early times. Iron ore occurs throughout the whole length of the Cantabrian Mountains on the northern coast of Spain, in Navarre, through the Basque Provinces, Santander and Asturias to Northern Portugal. Other large deposits are known in eastern and southern Spain, in the Provinces of Murcia, Almeria, Seville and Malaga. It has however, owing to difficulties of transport, been worked only near the coast, but many great ore bodies which exist inland—in Leon, Old Castile, Aragon, Andalusia and Murcia—are now being opened up. †

The most important deposits, or at least those which up to the present time have been worked far more extensively than any others, are those which are situated in the district of Vizcaya, in the Basque Provinces, and which, lying near Bilbao from which point the output is shipped, are known as the Bilbao Iron Deposits. These deposits are situated on the northern slope of the Cantabrian Mountains. The ground is for the most part hilly or mountainous, with very little flat land even along the sea shore. The ore lies chiefly at altitudes of between 600 and 1,100 feet. The most important of these Bilbao Iron Ores are those of Somorrostro and Orcanera, the former of which has been worked continuously for several hundred years, and it is believed that it is these deposits which are referred to by the Elder Pliny in the first century of our era when, in his Natural History, he says: "In the part of the Cantabrian coast which is washed by the ocean, there rises a high and steep mountain, which marvellous to relate is composed entirely of iron."

† Zeit. für. Prak. Geol., Nov., 1900.

It was from these ores that the metal for the celebrated Toledo blades was obtained, and in fact in the time of Shakespeare these deposits were so renowned that the term *Bilbo* was employed to designate various objects of iron and steel, as sword blades, fetters, etc., and so we find Falstaff (in the *Merry Wives of Windsor*) speaking of himself as "compassed like a good bilbo in the circumference of a peck," and in *Hamlet* a situation described as "worse than the mutines in the bilboes."

These Bilbao deposits however were first worked on a very large scale when the great demand for ores of this particular class was created by the introduction of the Bessemer process, and there are now (1899) in the Bilbao District, no less than 204 iron mines. The following figures will show the rapid increase in the production of iron ore in the District of Vizcaya:—

1861	54,000	tons.
1870	268,500	"
1880	2,345,000	"
1890	4,272,918	"
1899	6,146,542	"

Almost the entire amount in 1899 was exported, only 621,165 tons, or 6.7 p.c. of the total amount mined, being smelted in Spain. The ore is shipped chiefly to England, although a considerable amount is sent also to Germany. In 1899 the shipments to Great Britain, Germany and the United States of America were as follows:—

Great Britain	3,955,000	tons.
Germany	550,000	"
United States of America	75,000	"

The small shipments to the United States are owing to great fluctuations in freight rates between Spain and North America. It is important to note that 87½ p.c. of the iron ore imported into Great Britain comes from Spain and chiefly from these Bilbao deposits.

Bilbao, which is the chief port of north-eastern Spain, is situated on the River Nervion, 6 miles from the sea; the name Bilbao being derived from the Basque word *Bulibao*, which means "Town on the Plain." In addition to being an excellent port it has abundant rail-

Workings near the Esperanza Mine.
Afford Campanil.

way communication with the surrounding country. The river all the way down from Bilbao to the sea presents a busy scene, being filled with ships flying the flags of all nations, loading iron ore and other products at the almost continuous succession of wharves and landing stages which occupy the bank of the river. The bulk of the Bilbao ore as shown in the accompanying map is in the Somorrostro District, about Triano and Orcanera, some 6 or 7 miles west of the city of Bilbao on a high ridge immediately south of the railway. It is reached by taking the train to Ortuella from which place good roads lead to the mines. Great ore dumps are seen by the side of the railway all along the base of the Somorrostro ridge, the ore being carried down from the mines by all sorts of conveyances, from the picturesque but slow moving Basque cart drawn by a pair of oxen, (See Plate 6), to great systems of overhead wire rope tramways of modern construction.

The most extensive occurrence (Triano, Ventura, etc.) is irregular in shape, about two miles long and at Mt. Triano five-eighths of a mile wide, with a maximum thickness according to Kendall § of 220 feet.

The country rock is here Upper Cretaceous in age and has the form of a saddle, corresponding in direction with the shore, and the ore deposits are found on both sides of this. The Cretaceous shows the following succession in descending order:—

1. Light grey shale, very calcareous.
2. Grey limestone, (about 250 feet thick).
3. Dark micaceous sandstone, calcareous.

The strata where the bulk of the iron deposits occur have a general northeast dip which shows however many variations and disturbances. Their present attitude is the result of the upheaval of the Cantabrian Mountains in Tertiary times.

The ore occurs exclusively in connection with the limestone and is thus limited in depth at any point by the lower surface of that rock. This is very important, showing, as it does, that the deposits are

§ The Iron Ores of Spain. Trans. of the Fed. Inst. Mining Eng. Vol. III, 1891-92, p. 607.

essentially superficial in character and extent. The erroneous notion that in the case of the Bilbao deposits we have to do with "mountains of ore," arises mainly from the fact that the slopes of the hills coincide in some places with the dip of the limestone, and this rock having been replaced by ore, the whole hill or mountain seems to the casual observer to be a mass of iron ore, while, as a matter of fact, the ore is present merely as a superficial crust or coating.

The various ore bodies have an irregular elongated form, their longer axes coinciding with one another and with the strike of the strata. The relations of the sandstone, limestone and shale to one another and to the iron ore are well seen in accompanying sections. In one of the Triano sections (Figure 1) the overlying covering of shale is still preserved at the northern end. The other Triano section (Figure 2) shows the limestone entirely removed and replaced by ore in the flat portion of the area about the Concha and Adela Mines, the ore resting directly upon the underlying sandstones. In almost every part of the area the ore appears with a denuded surface, and is either actually exposed to view or concealed by a thin superficial covering. Where the limestone has been completely removed it lies directly on the surface of the sandstone. The ore deposits being thus essentially superficial in character, there are no *mines*, properly speaking, in the Bilbao District.

The ores are of five classes, and are designated locally as follows:—

1. *Vena.*—Red Hematite; compact, soft or sometimes powdery. Generally the purest of the ores, holding about 64 p.c. of iron. It was the only ore used in former times to supply the Catalan forges. Very little of it now remains.

2. *Campanil.*—Red Hematite; compact and crystalline, with numerous little drusy cavities lined with calcite. Said to derive its name from the ringing or bell-like sound which it gives out when struck with a hammer. It is the best of the ores, with the exception of *Vena*, and is one of the chief ores in the Triano Mines. It strongly resembles the hematites of Whitehaven and Furness. It may be said to carry about 55 to 58 p.c. of iron with 4 to 8 p.c. of lime.

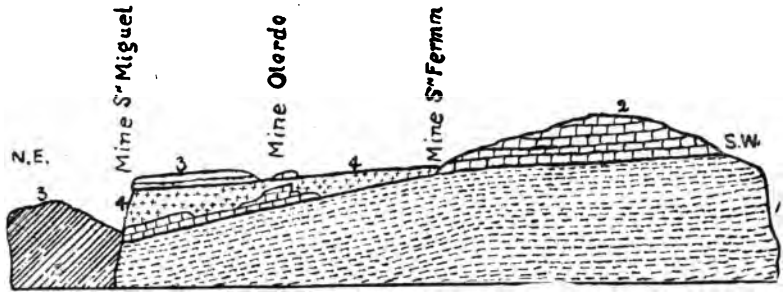

FIG. 1

Profile of the Triano District, between San Miguel Mine & San Fernin Mine.

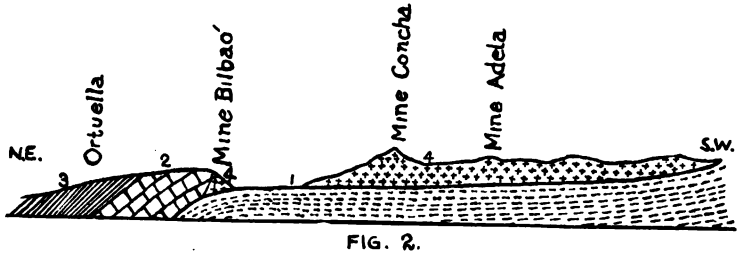

FIG. 2.

Profile of the Triano District between Ortuella & the Adela Ore Bed.

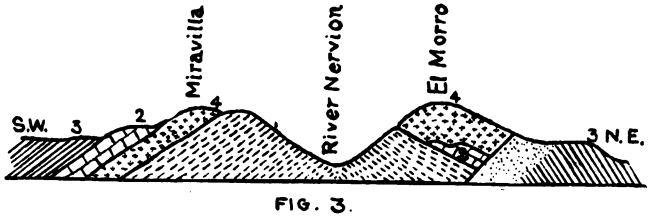

FIG. 3.

Profile showing the relation between the Miravilla & El Morro deposits.

1. Sandstone
2. Compact Limestone
3. Argillaceous Limestone
4. Iron Ore.

"CHIRTA"

Residual mantle of ferruginous clay with nodules of limonite scattered through it. The underlying limestone is seen protruding through the "Chirta," in the background. The method of working the deposit and preparing the limonite for shipment is also shown.

3. *Rubio.*—Limonite, carrying about 55 p.c. of iron, but usually more or less siliceous.

4. *Chirta.*—A ferruginous clay, with limonite nodules scattered thickly through it.

5. *Carbonato.*—Siderite, carrying about 44 p.c. of iron. Found almost exclusively at or near the base of the hematite or limonite deposits, and can be seen to pass into them. It was undoubtedly the primary ore and has by its alteration given rise to the *Vena*, *Campanil* and *Rubio.*

These ores are all very low in phosphorus. The Carbonato often contains a small amount of sulphur, but as it is roasted before exportation, this impurity is for the most part driven off.

The following are analyses of samples of the several varieties:—

	Vena.	Campanil	Rubio.	Carbonato
Ferric oxide	90.70	84.00	79.96	5.31
Ferrous oxide	....	....	....	50.18
Manganous oxide	1.30	1.90	.70	1.00
Alumina	.15	....	1.44	
Lime	1.00	4.60	1.00	.87
Magnesia	.02	....	.55	3.21
Silica	1.05	3.20	8.10	3.60
Carbonic acid				
Sulphuric acid	....	....	.10	....
Sulphur	.03	....	....	trace
Phosphoric acid	....	trace	.03	
Water and carbonic acid	5.40	6.00	....	36.28
Water	....	....	8.25	
	99.65	99.70	100.13	100.45
Metallic iron	63.49	58.80	54.62	43.96

The workings are practically all open cuts with a few short tunnels. The accompanying photographs* show some of the principal occurrences in the Triano District. The first of these (Plate 1) shows the Esperanza "mine." An open cut in Campanil mixed with streaks of yellow ferruginous clay and limonite. The ore contains the little

* For those photographs I am indebted to Professor Ries of Cornell University, in whose company I had the pleasure last summer of visiting the deposits described in the present paper.

drusy cavities lined with calcite, mentioned in describing the ore, in great abundance, one or more being present in every hand specimen.

Another similar occurrence of Campanil, worked by a great open cut and tunnels, near the Esperanza, is shown in Plate 2.

The next workings which were visited presented a deposit of a different character, the so-called Chirta. It is a yellow ferruginous clay with nodules of limonite scattered abundantly through it. It lay upon the limestone, mantling it deeply, the bed rock however protruding in places, as seen in the background of the picture. The face of the clay bank was being torn down by workmen with picks, the material being then thoroughly disintegrated by means of implements resembling forked mattocks, and then screened. The several processes are shown in the photograph (Plate 3). In this way the limonite nodules are separated from the clay and the ore prepared for shipment.

In other workings near by, the limonite-bearing clay was mixed with water and passed through an inclined revolving cylinder, the inner surface of which was studded with spikes. As the material passed out of the lower end of the cylinder and down a gently inclined shallow trough, any large unbroken clay masses were picked out by a number of men and boys, and were thrown aside to be crushed and once more passed through the cylinder. The finer washed stuff consisted of the limonite nodules and the water carried away the clay. A rather clumsy process, entailing much labour, the wages of a man, however, being only two pesedas a day.

The origin of this Chirta is well seen in some or the neighbouring occurrences. (Plate 4). The underlying limestone where it is exposed on the higher ground or where it is laid bare by the removal of the Chirta by the pick of the workman, is seen to have undergone superficial solution giving rise to that peculiar surface form, often seen in the bare limestone districts of the Upper Alps and known as Karren structure. The edges of the limestone beds stand up like sharply pointed slabs, a form evidently produced by the solvent action of the rain or percolating waters upon the surface of the limestone, while the Chirta representing the insoluble residue, which has gradually accumulated from the solution

"CHIRTA."

Showing the peculiar pinnacled surface of the underlying limestone. The material is being shovelled into ox carts, in order that it may be taken to the mill to be washed.

of a very considerable body of limestone, remains as a mantle upon the surface of solution and in pockets between the Karren. Much of the iron oxide has gathered itself together by concretionary processes into the limonite nodules which constitute the ore.

In another immense open cut or quarry, worked in benches and known as the San Benito property, the Rubio and Carbonato were found. A photograph of this is shown in Plate 5. The Carbonato or Siderite has a banded appearance and seems, in places at least, to be interbedded with the limestone. It is seen only in the lower levels of the cut, being covered by the porous limonite known as Rubio, which is the superficial alteration product of the Carbonato and can be observed to pass into it, working downward along joint planes and fissures in the siderite and often enclosing blocks of the latter not yet entirely altered. At the time of our visit, the white Carbonato and dark Rubio were being worked together along a face in the cutting where they occurred intimately associated, one passing into the other.

The Carbonato is calcined before being shipped, in furnaces situated on the lower slopes of the cut.

The origin of the ores seems to be as follows:—

The limestones themselves and especially the overlying calcareous shales, contained as these rocks so frequently do, a certain amount of iron disseminated through them in the form of various ferruginous compounds. The country during later Tertiary and Quaternary times was subjected to long continued denudation. The calcareous strata under these circumstances were dissolved and the iron passing downward in solution was, in the lower portion of the limestones, converted into carbonate of iron, which may therefore be considered as the primary ore, being the first ore concentrated in bodies of considerable size.

As the denudation proceeded, the calcareous shales and the limestones, being thoroughly leached out, left their insoluble residues as a mantle of residual clay, and under the oxydizing influence of the air and oxygenated waters, much of the iron instead of being removed by the waters was left behind in the form of insoluble oxides,—Limonite or Hematite, "Chirta" or "Campanil"—mixed with ferruginous clays.

As the surface of the country became lowered, the deeper bodies of Carbonato also became oxidized to Rubio—and the deposits assumed their present form. The concentration is undoubtedly going forward at the present time.

Farther to the east along the same line of folding, in the Pyrenees, as for instance at the well known Rancie Mines near Vicdessos, there are also iron ore deposits in the form of bedded veins of limonite, occurring in limestone and passing over in depth into siderite. The strata however here being highly tilted, the deposits follow the limestones down to great depths and are not confined to the surface as in the case of the Bilbao ores.

The Bilbao ores in their relations and mode of occurrence bear a strong resemblance to the limonite deposits of the great limestone valleys of central and eastern Pennsylvania, which have been worked for the production of iron ever since the rise of this industry in America. These have been made the subject of a recent paper by Mr. T. C. Hopkins,† who shows that they occur chiefly in the residual clays formed by the solution or disintegration of the Ordovician and Cambrian limestones and slates underlying these portions of Pennsylvania, the original source of the iron being the strata by whose decay the clays in question were formed, and through which strata it was originally disseminated chiefly in the form of carbonate.

It is stated that the Bilbao ores are steadily degenerating in quality,‡ and also that the deposits are rapidly approaching exhaustion. Lying altogether in the limestones and being thus essentially superficial deposits, exposed and worked over the whole surface simultaneously, it would seem that they have seen their best days. "We are continually hearing that the deposits are almost exhausted," said a Spanish ore shipper, "but year by year we have a larger output." This very fact, however, is hastening on the end. But while these deposits may be and probably are approaching exhaustion, many new deposits, as has been mentioned, are being opened up farther inland, so that the supply of Spanish ore will probably continue without serious diminution for at least some years to come.

† Cambro-Silurian Limonite Ores of Pennsylvania. Bull. of the Geol. Soc. of America, vol. 11, 1900.

‡ See Paper by Kayser, in Stahl and Eisen, vol. xviii, p. 373.

PLATE V.

SAN BENITO PROPERTY.

Yields Rubio and Carbonato.

PLATE VI.

SCENE ON ROAD BETWEEN ORTUELLA AND TRIANO.

Basque ox cart employed to carry ore.